Proceedings—Fire Effects on Rare and Endangered Species and Habitats Conference, Nov. 13-16, 1995. Coeur d'Alene, Idaho.

Effects of the Rat and Hatchery Creek Fires on Four Rare Plant Species

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Introduction

Fire, particularly on the east slope of the Cascades, has historically been a significant environmental factor that may have influenced the development of rare species. Mutch (1970) proposes that fire-dependent plant communities burn readily because natural selection has favored flammable characteristics. Agee (1993) points out that such a hypothesis proposed at the community level is improbable, but at the species level has some intriguing aspects. It is possible that fire, in combination with other environmental factors in the Wenatchee Mountains, influenced evolutionary pathways leading to some rare species of the area. At the very least, these rare species, like some other common species, have traits that provide competitive advantages in fire prone environments.

The Wenatchee Mountains are botanically diverse, supporting a number of regional and local endemics. Such a rich diversity of plant life probably resulted from an interaction of a variety of factors which not only include fire, but geology, climate, and topography (which creates varied environmental conditions). One explanation concerns the areas' recent geological past. The Wenatchee Mountains escaped the last major glacial advance, which occurred about 10,000 years ago. The continental ice sheet moved south in the vicinity of Chelan (Alt and Hyndman 1984). Closely related species probably came into close contact during this time and hybridization, followed by inbreeding or sympatric speciation, may have occurred (Lewis 1966, Grant 1981). Other possibilities are that rare species are simply relict populations still slowly migrating away from the glacial refugium or becoming extinct.

Unique and diverse climatic conditions may have also contributed to the development of rare species. The Wenatchee Mountains lie in the rainshadow that develops in the lee of the Cascade crest. The climatic tension in this zone between the maritime air masses of the west and the arid steppe to the east, along with the region's diverse soils and frequent fires, could provide the selective pressures necessary for sympatric speciation (Grant 1981).

In 1994, the Rat and Hatchery Creek fires came together, burning 17,063 hectares (42,163 acres) near Leavenworth, Washington (Figure 1). Fire intensity and severity varied depending on a number of factors, including community type and fuel accumulation. Within the Leavenworth Ranger District, Wenatchee National Forest, 11 rare plant species were affected by the fires. Of these, *Delphinium viridescens*, *Cypripedium fasciculatum*, *Silene seelyi*, and *Orobanche pinorum* were chosen for the current study. These four species are often the focus of district management activities.

Effective conservation management of rare species requires a functional knowledge of biological and ecological attributes. For some species, specific habitat requirements must be maintained in order to have viable populations. *Delphinium viridescens*, for example, requires adequate soil moisture during the spring and dry soil conditions in late summer. Changes in site hydrology cause a dramatic decline in population numbers. Conservation strategies for these types of species must therefore include habitat maintenance. Other species may have unique biological requirements which deserve special attention. *Cypripedium fasciculatum* is an obligate out-crosser and has a relatively low reproductive success rate (Harrod and Knecht 1994), suggesting that pollinators are uncommon and/or ineffectual. If pollinators are uncommon, then conservation measures should include conservation and management of required pollinators. In addition, species' response to fire disturbance, like habitat requirements or reproduction, is an important piece of information for the development of conservation strategies.

We designed our study to address several questions about these four species' relationship to fire: Does fire stimulate, decrease or not affect vegetative growth and vigor? Does fire affect species' density? How does fire affect reproductive potential?

Delphinium viridescens

Delphinium viridescens Leiberg (Wenatchee larkspur) is a narrow endemic occurring in the Wenatchee Mountains of Washington. The species has an "endangered" status in Washington State and is a federal candidate (category 1) for listing and protection under the Endangered Species Act. There are 21 known occurrences, fifteen of which occur on Wenatchee National Forest land.

This species is a stout, rhizomatous perennial with fertile stalks ranging from 6 to 20 dm in height. Both single and compound inflorescences can be found, but most stems consist of a single, narrow raceme, about 4 dm long with 30 to 50 flowers (Varney 1979, Loomis 1985). Unlike some of the more common *Delphinium* species in the area, *D. viridescens* flowers are rather drab, with green to purple petals and purplish sepals. Plants flower in late June and early July and fruit by mid- to late August.

Seasonally moist meadows or riparian areas provide habitat for *D. viridescens*. Many of the larger populations occur in meadows created by landslides which occurred hundreds or perhaps thousands of years ago (Carl Davis, Soils Scientist, Wenatchee National Forest, pers. comm.). These meadows provide early spring moisture (soils are saturated) which appears to be critical for species' survival. Soils are clay loam with organic contents greater than or equal to 10% (Loomis 1985). In May, soil moisture averages 60% and can reach 142%, but by August it decreases to 25% with some sites as low as 5% (Loomis 1985). Aerial stem distribution within habitats approximates optimum soil-moisture conditions.

Study Area

The Rat Creek Fire burned through two populations of *D. viridescens*, both occurring in relatively narrow riparian areas. One study site, near Camas Land south of State Highway 97 (Figure 1), was selected based on its abundance of plants and accessibility. At this location, fire burned with low intensity, consuming the duff layer, herbs, and shrubs, but not woody material larger than about 5 or 7 cm. The burned study area is almost completely on a Natural Area Preserve managed by the Washington State Department of Natural Resources, but one plot was placed on private land owned by Longview Fibre Corporation. The unburned comparative populations are located on Wenatchee National Forest land near Camas Land and Tiptop Mountain (Figure 1). Sites were visited in late July and August, 1995.

Methods

The sampling method follows closely the monitoring guidelines developed by Harrod and Yen (1992). This monitoring plan was designed to collect demographic information over a period of several years. No previous monitoring had occurred in the burned population. However, the intent is to continue monitoring the burned population in a manner consistent with unburned sites which have been studied since 1989.

Seven 5 m radius circular plots were established where *D. viridescens* burned. Plots were selected based on a presence of *D. viridescens* individuals which were scattered throughout the burned riparian area. Seven 5 m radius circular unburned plots were selected at random from plots previously established for the monitoring study (Harrod and Yen 1992). Each plot was divided into four quadrants separated by transects placed as radii to the circular plot on true cardinal compass directions. The first 10 aerial stems encountered in a clockwise manner in the NE quadrant were selected for morphological measurements. If less than 10 stems were encountered, then the SE quadrant was used for the balance. The following morphological data were collected:

1. height of stem (cm);
2. number of flowers/fruits; and
3. length and width of one lower, middle, and upper leaf (cm).

For purposes of analysis, length and width of leaves were multiplied to obtain an index of leaf area (cm^2).

Each set of morphological data was analyzed by analysis of variance (ANOVA) using a completely randomized design, with an alpha level preset at 5%.

Results

The means of all morphological measurements, except lower leaf area (not statistically analyzed), were significantly greater in burned area plants compared to plants in unburned plots (Table 1). Mean aerial stem height the burned treatment was nearly 1.5 times taller than those in unburned plots — 134.2 cm and 95.6 cm, respectively (SE = 3.89). Burned plot stems had nearly 2.5 times the mean number of flowers and fruits than did stems from unburned plots — 70.0 and 28.8, respectively (SE = 5.26). The number of flowers and fruits on stems in burned plots varied from as high as 236 to as few as 1. The low numbers within this range appeared to be the result of herbivory. Because data was collected late in the season, many of the leaves had withered and fallen. As a result, there were too few lower leaves from burned plot plants to be statistically analyzed.

Table 1. Mean morphological measurements of *Delphinium viridescens* collected at both burned and unburned sites. All values for each character except lower leaf area (which was not statistically analyzed) are significantly different.

	Treatment[1]	
Character[2]	Burned	Unburned
Height	134.2 (70)	95.6 (70)
Flwrs/Frts	70.0 (70)	28.8 (70)
Lower Leaf	154.1 (59)	78.3 (6)
Middle Leaf	152.3 (62)	47.1 (15)
Upper Leaf	119.0 (61)	31.2 (19)

[1]Numbers of observations are provide in parentheses.
[2]Height is cm, flowers/fruits are counts, and leaf measurements are cm^2.

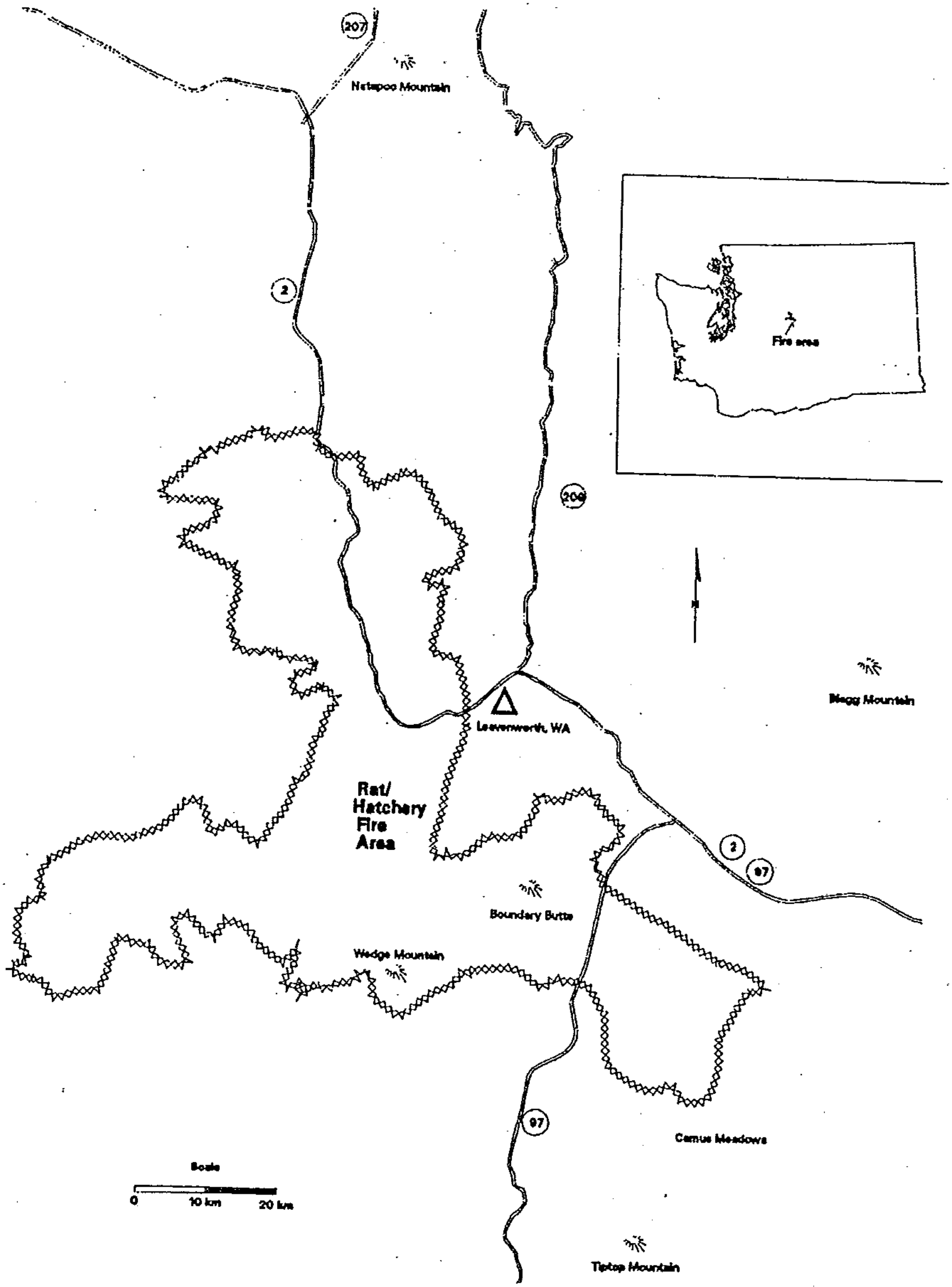

Figure 1. Vicinity map of the Rat and Hatchery Creek fire complex

Cypripedium fasciculatum

Cypripedium fasciculatum Kell. ex Watson (clustered lady's-slipper) is a rare terrestrial orchid which occurs from Washington to California and in scattered locations in Idaho, Montana, Colorado, Wyoming, and Utah (Brownell and Catling 1987). This species has a "threatened" status for the state of Washington and is currently considered a species of concern by the U.S. Fish and Wildlife Service (formally federal candidate category 2). There are 24 known occurrences on the Leavenworth Ranger District, Wenatchee National Forest.

The species is a low rhizomatous perennial that has a number of "clustered" aerial stems arising from a single rhizome. Stems are covered with woolly hairs and a sheathing bract near the ground. At time of flowering, the mean height of aerial stems is 9.8 cm (Harrod and Everett, unpubl. paper) with a pair of subopposite leaves at or above midlength. After pollination, which requires a biotic vector (Harrod and Knecht 1994), mean aerial stem height increases to 15.3 cm as result of peduncle growth. This apparently is an adaptation for increased seed dispersal (Harrod and Everett unpubl. paper).

Habitats are variable throughout the Cascade Range and elsewhere. In California, Barker (1983) notes that the habitat of *C. fasciculatum* cannot be closely defined. There is no apparent restriction to parent material since populations have been found on ultrabasics, granitics, schists, limestone, quartz-diorite (Barker 1983), and serpentine (Fowlie 1988). Barker (1983) also states that populations in California are found in numerous plant communities, including mixed evergreen, mixed conifer, *Pseudotsuga menziesii*, and *Pinus* spp. /*Quercus kelloggii* forests. In Oregon, Kagan (1990) notes that the species occurs primarily in older *P. menziesii* forests on old stream terraces. In Montana, Elliman and Dalton (1995) find *C. fasciculatum* in forest stands dominated by *P. menziesii* and *P. ponderosa* which are seral to *Abies grandis* and *Thuja plicata*. In Washington, habitat varies widely between east and west sides of the Cascades. On the Leavenworth Ranger District, Knecht and Harrod (unpubl. data) find the species primarily in the *A. grandis* series with high tree densities of *A. grandis* and *P. menziesii* — 86 and 115 trees per hectare, respectively.

Study Area

This study represents a portion of a thesis project by D.E. Knecht which examines the population ecology of *C. fasciculatum* throughout the Cascade Range. Data used in this analysis were taken from four plots, each on different sites, located on the Leavenworth Ranger District, Wenatchee National Forest. The Rat Creek Fire burned through one population near Boundary Butte, southeast of Leavenworth (Figure 1). The fire burned at varying intensities throughout the plot burning some plants and not others. Comparative unburned sites are located near Camas Land, Natapoc Ridge, and Blagg Mountain (Figure 1). Selection criteria for sites included population size (> 20 aerial stems) and accessibility. Sites were visited during June of 1994 and 1995.

Methods

One permanent 10 m x 6 m rectangular plot was established at each site. The area with the greatest density of *C. fasciculatum* within each site was designated plot center and was marked with a metal rebar. Percent cover of all plant species occurring within plots was ocularly estimated. Plants were identified using the *Flora of the Pacific Northwest* (Hitchcock and Cronquist 1973). For purposes of analysis, vegetation was divided into four lifeform categories: overstory (trees), shrubs (multiple stem, woody plants), forbs (herbaceous plants other than grasses), and graminoids. A densiometer was used at plot center to measure percent canopy coverage.

Within each plot, all *C. fasciculatum* stems were located and the following data were collected:

1. number of individual stems;
2. number of clumps (all stems located less than 20 cm from another individual stem were considered to be within the same clump);
3. number of stems per clump; and
4. number of stems with fruits.

In addition, thirty aerial stems within each plot (less if not available) were marked with metal tags and the following data were collected:

1. number of flowers per stem;
2. number of fruits per stem;
3. total stem height as measured from the soil surface to the leaf bract;
4. leaf width at its widest point; and
5. leaf length measured from the stem to the leaf tip.

At the burned site, excavations were made where plants had been in 1994, but did not produce aerial stems in 1995. The intent was to determine if the rhizomes were dead or dormant.

Morphological data were analyzed by a 2 x 4 factorial ANOVA, with an alpha level preset at 5%. The two levels of factor A were 'year' (1994 and 1995), while the four levels of factor B were 'sites' (1 burned and 3 unburned). Vegetation cover was not statistically analyzed because only one burned site existed.

Results

Mean percent cover of overstory, shrubs, forbs, and graminoids at the burned site decreased in 1995, following the fire event (Table 2). However, three new species (*Osmorhiza chilensis*, *Ceanothus velutinus*, and *Aster foliaceous*) were present in 1995 at the burned site (Table

Table 2. Mean percent cover for all species present at the Boundary Butte *Cypripedium fasciculatum* site before and after the burn.

	% Cover 1994 (pre-fire)	% Cover 1995 (post-fire)
Overstory		
Pseudotsuga menziesii	45	40
Pinus ponderosa	15	15
Abies grandis	15	10
Shrub		
Rosa gymnocarpa	30	15
Spiraea betulifolia	10	10
Pachistima myrsinites	5	1
Amelanchier alnifolia	2	0
Ceanothus velutinus	0	1
Forb		
Cypripedium fasciculatum	10	8
Arenaria macrophylla	10	3
Balsamorhiza sagittata	10	3
Arnica cordifolia	5	15
Antennaria racemosa	5	1
Anemone oregana	5	5
Hieracium albiflorum	3	1
Lathyrus pauciflorus	2	2
Lupinus spp.	1	1
Goodyera oblongifolia	1	0
Luina nardosmia	1	1
Osmorhiza chilensis	0	1
Aster foliaceus	0	1
Graminoid		
Carex geyeri	15	2
Calamagrostis rubescens	2	5

2). Also, percent cover of *Arnica cordifolia* and *Calamagrostis rubescens* increased notably at the burned site (Table 2).

There was a significant increase in the total number of aerial stems produced at all sites in 1995, including the burned plot, even though there were four fewer clumps present at that site. There were no significant differences in the number of clumps per plot, nor the mean number of stems per clump between 1994 and 1995. The number of plants with fruits changed by no more than 4% at all sites between years, except the burned site which decreased by 33%.

At each site, there was no significant difference between 1994 and 1995 in the number of flowers produced, leaf length, or plant height (Table 3). There was a significant decrease in the number of fruits per stem at the burned site in 1995 compared to 1994, while there was no significant change at any other site (Table 3). Leaf width was not significantly different between years at any sites except Camas, where leaf width was significantly greater in 1995 (Table 3).

The excavations of 1994 plants that did not occur in 1995 did not reveal any dormant rhizomes. It was noted that the duff layer was eliminated by fire at these plant locations.

Silene seelyi

Silene seelyi Morton & Thompson (Seely's catchfly) is a local endemic in the Wenatchee Mountains of Chelan and Kittitas Counties, Washington. It currently has a "threatened" status in the state of Washington and is considered a species of concern by the U.S. Fish and Wildlife Service. To date, there are 15 known occurrences on the Leavenworth Ranger District, Wenatchee National Forest.

This species is a herbaceous perennial, each plant consisting of several stems which originate from a single,

Table 3. Mean morphological and reproductive measurements of *Cypripedium fasciculatum* collected at both burned and unburned sites.

		Site[1]			
Character[2,3]	Year	Boundary Butte (30) (burned)	Camas (30) (burned)	Natapoc (30) (burned)	Derby (9) (unburned)
Flowers	1994	2.2	2.8	3.6	1.5
	1995	2.6	3.3	3.4	2.3
Fruits	1994	1.3*	1.6	1.4	1.5
	1995	.48*	1.0	1.0	.69
Plant Height	1994	5.5	5.4	7.6	8.2
	1995	5.7	5.9	7.7	7.6
Leaf Width	1994	5.5	5.3*	6.9	5.5
	1995	5.9	6.2*	7.1	5.6
Leaf Length	1994	8.3	8.5	10.1	8.8
	1995	8.1	9.0	10.3	9.2

[1]Number of observations are provided in parentheses.
[2]Flowers and fruits are counts, and height, width, and length are cm.
[3]Means within the same column marked with an asterisk (*) are significantly different.

branched caudex. The small flowers are white to purple tinged and are present from May through August. No information exists regarding its reproductive biology.

Habitat requirements are yet to be described. However, we have observed plants growing in rock crevices and talus slopes, mostly on north- or west-facing slopes. It appears as if there are no specific substrate requirements since they are found on variety of parent materials. *Silene seelyi* has a clumped-scattered distribution pattern with plants growing in clumps, which are scattered within the habitat boundaries for each population.

Study Area

The Rat Creek fire burned through portions of one large known population near Wedge Mountain and this site was selected for this study (Figure 1). This site is located on Wenatchee National Forest land. Overall, fire burned with low intensity because of the rocky habitat, but all organic material in rock crevices was often completely consumed. The Hatchery Creek Fire burned over other known locations of *S. seelyi*, but inspection of those sites revealed that there was no evidence of fire actually burning in close proximity to plants. The study site was visited in the 1995 field season.

Methods

Five 25 cm x 50 cm rectangular plots were established around one to several clumps of *S. seelyi*, two burned and three unburned. The corners of the plots were permanently marked with red paint, and a number labeled on the rock face near the plot. In each plot, the following data were collected:

1. total stem density;
2. stem density of vegetative and reproductive;
3. percent cover of *S. seelyi*, any associated species, debris, soil, or bare rock; and
4. clump diameter in two perpendicular directions (clumps defined by groups of stems which are less than 5 cm apart).

In addition, three stems within each plot were randomly selected and the following morphological data were collected:

1. height;
2. number of flowers and fruits; and
3. length, width, and shape of 15 leaves (all when fewer).

Each set of morphological data was analyzed by analysis of variance (ANOVA) using a completely randomized design, with an alpha level preset at 5%. Percent cover data were transformed with an arcsin of the percentage and subjected to a completely randomized design ANOVA. Density, population structure, and clump area were analyzed with a Student's t-test.

Results

Mean number of aerial stems per 50 cm^2 in the unburned treatment was 50 and 25 in the burned treatment — these means were not significantly different (Table 4). Mean number of both reproductive and vegetative stems per 50 cm^2 were not significantly different in burned and unburned treatments. Mean *S. seelyi* clump area in burned and unburned treatments was not significantly different (Table 4).

Table 4. Mean number of reproductive and vegetative stems, and mean clump area for *Silene seelyi* burned and unburned treatments. There were no significant differences between the treatments.

Character[2]	Treatment[1] Burned (2)	Unburned (3)
Total stem density	26	50
Reproductive stems	17	31
Vegetative stems	9	19
Clump area	601	512

[1]Numbers of plots are provided in parentheses.
[2]Units for total density, reproductive stems and vegetative stems are counts; clump area are cm^2.

Silene seelyi plants in the burned treatment had a mean cover of 39%, while unburned had 24 % mean cover, but these differences were not significant (Table 5). There were no significant differences in mean percent cover for graminoids, forbs, shrubs, mosses, or lichens when comparing burned and unburned treatments (Table 5).

Table 5. Mean percent cover of *Silene seelyi*, forbs, graminoids, shrubs, mosses, and lichens at burned and unburned sites. No significant differences were found between treatments.

	S. seelyi	Forb	Graminoid	Shrub	Moss	Lichen
Treatment						
Burned	39	2.5	0	2.5	4.5	7.5
Unburned	24	11	0	0	17	8.3

There were no significant differences in the mean number of flowers/fruits per stem between burned and unburned treatments (Table 6). Mean stem height for burned plants was 17 cm and 12 cm for unburned plants — these means were not were not significantly different. Mean leaf length and width were similar between burned and unburned, no significant differences were seen (Table 6). Leaf shape was not analyzed, but percent of leaves of each five shapes were similar between treatments.

Table 6. Mean morphological and reproductive measurements collected at both burned and unburned *Silene seelyi* plots. Leaf shape was not statistically analyzed. All other variables had no significant difference.

Character[2]	Treatment[1] Burned	Unburned
Flwrs/Frts	2 (6)	3 (9)
Stem height	16.7 (6)	12.0 (9)
Leaf length	1.3 (83)	1.4 (124)
Leaf width	0.55 (83)	0.59 (124)
Leaf Shape[3]:		
Elliptical	30.3	35.3
Elliptical/ovate	2.2	0
Elliptical/oblanceolate	5.6	1.7
Elliptical/lanceolate	27.0	26.7
Lanceolate	34.8	36.2

[1]Numbers of observations are provided in parentheses.
[2]Height, length, and width are cm, flowers and fruits are counts; and leaf shape is percent.
[3]Number of leaves observed: 83 burned, 124 unburned.

Orobanche pinorum

Orobanche pinorum Geyer (pine broomrape) occurs in scattered locations in Washington, northern Idaho, Oregon, and northwestern California (Hitchcock and Cronquist 1973). It has a "sensitive" status for the state of Washington, but has no current federal status. On the Leavenworth Ranger District, Wenatchee National Forest, this uncommon species is unusually abundant, with more than 20 known occurrences. Many sites have five or fewer individuals emerge in a season, and seasons can pass without a single new stem. Since individual plants that emerge die at season's end, it is difficult to ascertain whether a known population with no emerging plants has become extinct.

This achlorophyllus plant is an obligate root parasite, its only confirmed host being *Holodiscus discolor*. It receives its entire complement of water and nutrition from its host. Stems originate annually from a haustorial tubercle, emerge in mid- to late June, and fruit in mid-July through early August. Each plant typically produces 50-150 flowers with 500-1000 seeds per fruit (Ellis, unpubl. data). Ellis, Taylor, and Harrod (1994) found that *O. pinorum* is facultatively autogamous and it apparently reproduces only by seed. Although most seed production probably occurs autogamously, two potential pollinators have been identified — *Ashmeadiella cactorum* and *Osmia exigua*, both solitary bees (Ellis, unpubl. data). Seed germination and establishment are possibly dependent upon the chance encounter with host root exudate (Brown et al. 1951, Kuijt 1969, Whitney and Carsten 1981). Seeds apparently work their way down through the soil until near contact with exudate from a host root occurs.

Orobanche pinorum is often found in *P. menziesii* dry forest associations with incomplete upper canopies between 460 and 1220 meters in elevation.Slopes are often steep (25-50%), with predominately loose soils. These sites frequently have scattered herb and low shrub layers, and a tall shrub layer dominated by *H. discolor*. Percent canopy closure is highly variable, but larger populations often are found in canopy gaps. *Holodiscus discolor* is often abundant in these open areas, providing more potential hosts for *O. pinorum*.

Study Area

The Tyee Fire near Chelan, and the Hatchery Creek Fire near Leavenworth, each burned through a known population of *O. pinorum* (Figure 1). Both sites are located on Wenatchee National Forest land. Comparative unburned sites were selected near Chumstick Creek (Figure 1). Sites were visited in the 1995 field season.

Methods

These are methods that we intended to use if we found that plants emerged within the fire areas. The following data were to be collected in quadrangular plots encompassing populations: individual traits (stem height, crown dimensions, number of bud, flowers, and fruits), number of individuals, density of individuals, distribution of individuals, associated species, density of associated species, canopy cover, and comments on herbivory.

Results

We found no new individuals in either area that burned, therefore, no results arepresented. See Discussion for comments concerning this species.

Discussion

It is possible that some rare species have evolved certain requirements for disturbance. In the present study, *D. viridescens* did increase in size and reproductive potential in the first year following disturbance by fire, but whether or not fire is a required disturbance for the maintenance of this species remains to be determined. It is clear that *D. viridescens* is adapted to the fire environment and perhaps is able to take advantage of a decrease in competition and/or an increase in nutrient availability. Grime (1979) calls this type of strategy in plants, "competitors" in which phenotypic responses to frequent, low-intensity disturbance are the formation of "rapidly-repaired" leaf canopy through resprouting, or, perhaps in the case of *D. viridescens*, increased seed production and subsequent rapid recolonization.

Cypripedium fasciculatum appeared to respond vigorously when initially comparing number of aerial stems at the partially burned plot pre- and post-fire, however, analyses indicate that all plots increased in the number of aerial stems produced in 1995. This is likely the result of some other environmental condition rather than fire response. It does appear that the species cannot tolerate low intensity fire that eliminates the duff layer as indicated by a lack of rhizomes found in the excavations. However, some plants did survive fire where the duff layer was not eliminated. *Silene seelyi* does appear to tolerate fire, as shown by its presence in burned habitat. Whether *S. seelyi* responds by resprouting or colonizing burned area is unknown. Although we have no direct evidence that *O. pinorum* tolerates fire, its host is adapted to disturbance, including fire, by quickly resprouting. This may suggest that *O. pinorum* is not adversely affected by fire, and in fact, may benefit from an increase in *H. discolor* density.

Some plants may compensate for resources which may be limiting following a fire. An example of one such limiting resource is pollinator abundance. *Delphinium viridescens* has greater reproductive potential in the first year following fire. This may assure some level of seed production since pollinators may be scarce or absent. It appears as if pollinator abundance for *C. fasciculatum* has decreased which limits reproductive success, since the species is an obligate out-crosser (Harrod and Knecht 1994). Decreases in pollinators associated with fire would not influence reproductive success of *O. pinorum* since this species is primarily autogamous (Ellis, Taylor, and Harrod 1994).

An important potential effect of fire in regards to rare species involves changes in their habitat. Thomas and Carey (in press) found that *Aster curtus*, a rare species in the Puget Sound lowlands, was less abundant under a *P. menziesii* tree overstory than open prairie conditions, suggesting some dependance upon disturbance. *Pseudotsuga menziesii* has been increasing in the Puget Sound lowlands due to a decrease in fire frequency (Kruckeberg 1991, Clampitt 1993). The optimum habitat conditions for *C. fasciculatum* appear not to be found in early successional communities. Most populations are found in areas with relatively closed canopies that develop later in succession. This species may require a mycorrhizal symbiont not only in adult plants, but also for seed germination as found in other *Cypripedium* species (Arditti 1992). It is possible that the required symbiont(s) is only present in mid- to late-successional forest communities. Historically, suitable habitat conditions for *C. fasciculatum* likely shifted across the landscape over time or were found in fire refugia (Camp 1995).

Delphinium viridescens, in contrast to *C. fasciculatum*, has more restricted habitat requirements. This species must be able to tolerate fire in order to continually occupy its restricted habitat. Fire occurrence in the rocky habitat of *S. seelyi* is likely infrequent; therefore exerting little selective pressure on this species. However, this species does tolerate fire, as shown by its presence in rock crevices that burned in 1994. New microsites become available for colonization by *S. seelyi* when sites do burn. *Orobanche pinorum*, too, may benefit from fire or other disturbances. Open shrub-dominated habitat suitable to *O. pinorum* and its host, *H. discolor*, could include fire regimes with short fire-return intervals. The subsequent reduction of competing plants and the burst of new shoots along with requisite new roots of *H. discolor* (for seed germination) might enhance the establishment of *O. pinorum* in post-fire seasons. Also, some soil movement associated with fires may aid seeds in moving through the soil profile to come in contact with host roots.

Although fire effects on other rare plants in Washington apparently have not been reported, the importance of some other types of disturbances have been. *Artemisia campestris* var. *wormskioldii* was once common along gravelbars and floodplains of the Columbia River until dams were constructed, controlling the flow of water and eliminating such habitats (John Gamon, Botanist, Wash. Nat. Hert. Program, pers. comm.). This species may require periodic flooding to eliminate competition, provide suitable germination sites, or replenish nutrients. Holsinger and Gottlieb (1991), and references therein, note that *Trifolium stoloniferum* is apparently diminishing because it is adapted to the disturbed soil characteristics of bison wallows in the Great Plains, a habitat that is no longer present. Fire like other types of disturbance, may be a critical influence in the evolution of rare species. The results of this study indicate that some rare species have acquired characteristics which allow them to tolerate fire disturbance, while others simply avoid fire altogether. Knowing these responses will allow land managers to develop responsible management strategies.

Conclusions

Our preliminary results regarding *O. pinorum* and *S. seelyi* response to fire are inadequate to provide management recommendation. However, the result of this study indicate that *C. fasciculatum* is a fire-intolerant species and management of this species probably should not include prescribed fire. Our results regarding *D. viridescens* suggest that fire will increase immediate post-fire vigor. This suggests that, if appropriately used (e.g. timing, intensity, habitat conditions), prescribed fire could be an effective management tool for this species.

Post-fire monitoring should continue for all species studied. *Orobanche pinorum*, in particular, may have a delayed response to fire due to its complex life history. It will be important to monitor changes in associated species composition and their interactions with the study species. Additional monitoring sites need to be established at nonburned sites so that pre-burn data will be available if, or when, other sites burn.

Acknowledgements. We thank Longview Fibre Corporation for allowing access to their lands. We appreciate the field assistance of a number of individuals: Lauri Malmquist, Douglas Eitemiller, Cedar Drake, and Marilyn Knoll. Thoughtful reviews were provided by Ted Thomas, Terry Lillybridge, and Kristina Ernest. Figure 1 was developed in GIS by Jim Haberberger.

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